

# REPORT ON COLLAPSE OF TOWER.

(161)

MONTREAL, May 17, 1906.

*To His Excellency the Governor General in Council.*

MAY IT PLEASE YOUR EXCELLENCY:

The commissioners appointed by an Order in Council dated the ninth day of April, nineteen hundred and six, to jointly hold an investigation and to report upon an accident which occurred on the morning of the fifth of April, nineteen hundred and six, by the collapse of part of the tower in the West Block extension of the department buildings, in the city of Ottawa, with the instructions therein contained, have the honour to report:—

That in obedience to the instructions contained in said order, the commissioners commenced their investigation on the ninth day of April, nineteen hundred and six, by making a personal examination of the collapsed tower and thereafter holding meetings for the hearing of evidence, examining plans, specifications, and contract, and for making further and more minute examinations of the walls of the tower to ascertain how they were constructed and the quality of material used.

## MEETINGS.

Meetings were held in room number one hundred and three, in the Western Block, in the city of Ottawa, on the tenth, eighteenth, nineteenth, twentieth, twenty-fifth, twenty-sixth and twenty-seventh days of April ultimo.

## REPRESENTATION.

At these meetings the Department of Public Works was represented by D. H. McLean, barrister, of the city of Ottawa, assisted by E. L. Horwood, architect, of the same place, as expert, while George Goodwin, contractor, was represented by Charles Murphy, barrister, of the city of Ottawa, assisted by W. E. Doran, and F. S. Baker, architects, of the cities of Montreal and Toronto, respectively.

## WITNESSES.

At these meetings the evidence of witnesses produced by the Department of Public Works and George Goodwin, contractor, also witnesses summoned by the commissioners, was taken after the witnesses had been duly sworn by one of the commissioners, viz.:—

D. Ewart, chief architect of the department; L. F. Taylor, chief draughtsman in the architect's office; William Langdon, contractor, of the city of Kingston; E. S. Mattice, engineer, of the city of Montreal; William Stuart, contractor, of the city of Ottawa, and E. L. Horwood, architect, of the same place, witnesses produced by the Department of Public Works; and H. Holgate, engineer, of the city of Montreal; James Crawford, superintendent for G. Goodwin, contractor; W. E. Doran, architect, of the city of Montreal; F. S. Baker, architect, of the city of Toronto; James Morrison, foreman mason for G. Goodwin, contractor; William Sanders and James Evans, masons, employed by G. Goodwin in the erection of the tower, and Henry Bilodeau, roofer, of the city of Ottawa, witnesses produced by the contractor; also C. A. Mc-



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Cool, M.P., for Nipissing, and John Thompson, junior, barrister, of the city of Ottawa, witnesses summoned by the commissioners.

## DESCRIPTION OF TOWER.

From an examination of the contract, plans and evidence heard by the commissioners, it appears that the collapsed tower was a copy or a replica of the towers on the south elevation of the Western Block, and that in carrying out the work in the collapsed tower certain changes were made in the construction of the upper portion of the new tower not in accordance with the construction of the old towers.

The collapsed tower, according to the contract plans and as actually erected, consisted of a base twenty-five feet square rising to a height of about eleven feet above the ground. At this level the tower was reduced to twenty-three feet square and was continued at that size to a little above the roof of the extension, a height of fifty-four feet above the base.

At this level a water table consisting of three courses of dressed Ohio sandstone making a height for the three courses of four feet six inches was placed, this table was carried round on the four faces of the tower, and as each course of the tabling receded upon the one below it towards the inside of the tower, it caused the size of the tower to be reduced from twenty-three feet square below the water table to twenty feet square above it. The tower was then carried up twenty feet square to the roof, a height of seventeen feet above the tabling, and on each of the four faces there was a high pointed gable in stonework rising to an additional height of sixteen feet.

Above the stonework of the upper stage there was a high-pitched roof rising to a height of twenty-four feet above the stonework, or a total height of one hundred and ten feet from the ground, and above the roof there was an ornamental iron cresting and finial.

As the collapse of the tower appears to have occurred on the southeast angle, or at immediately below the water table, the commissioners were particular in ascertaining the dimensions of the north and east walls and the manner in which they were constructed, both below and above, and at the water table.

## CONSTRUCTION OF TOWER.

We find that the exterior walls of the tower, viz.: the north and east walls, from the top of the base and to within ten feet of the under side of the water table, a height of forty-four feet, were built with a facing of Nepean random rock-faced courses and with Ohio sandstone trimmings around window openings, and with Ohio sandstone angle quoins, water tables, bands, cornices, &c. The Nepean and Ohio sandstone being backed with rubble limestone masonry, making with the facing and backing a wall of two feet five inches thick; these walls were lined with four-inch brickwork, which, with an air space of one inch, gave a total thickness of two feet ten inches.

From the point forty-four feet above the base at which the brick lining terminated the walls were carried up to the under side of the water table of the full thickness of two feet ten inches in rubble masonry with the facing of Nepean stone.

The interior walls of the tower, viz.: the south and west walls, were constructed wholly of limestone rubble masonry with a uniform thickness of two feet ten inches from the level of the ground floor to the under side of the water table.

The walls of the upper stage of the tower on the four elevations, were faced with Nepean random rock-face courses backed up with limestone rubble masonry, making a wall two feet thick. As the outer face of these walls was set back one foot six inches inside of the line of the outer face of the wall below the water table, it brought the inside face of these walls eight inches inside of the inside face of the walls below the water table.

In the old towers of the south elevation there is an inside overhang of from twelve to fourteen inches stepped out in the masonry.



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In the collapsed tower a departure was made from this manner of construction and the overhang instead of being stepped out in masonry was supported on four heavy steel beams, one being placed on each side of the tower, the two beams which supported the overhang of the north and south walls were placed on a level with the first course of the water table, and had a length of twenty-one feet, so that when placed on the wall the ends were within one foot of the outside face of the walls below the tabling. The two beams which supported the overhang of the east and west walls were placed on top of the two steel beams which carried the north and south walls, and as they were only eighteen feet long they had little or no bearing on the walls, and concentrated their loads upon the twenty-one-foot beams.

In the old towers the quatrefoil panels are surface decorative features—not piercing the walls.

In the collapsed tower the quatrefoils were placed in the same relative position, but instead of being mere ornamental panels as in the old towers, they were perforated to form windows; the opening in the backing behind these windows was built four feet six inches wide by four feet high to springing of brick arch placed over these openings. On the jambs forming the sides of two of these openings the outer ends of each of the two twenty-one-foot steel beams rested, which supported the overhang of the north and south walls.

## QUALITY OF MASONRY.

After careful examination of the walls of the tower, a large portion of which we caused to be taken down to determine the exact character of the work, your commissioners are of the opinion that the direct cause of the collapse was the inferior quality of the material and workmanship supplied in its erection.

The specification called for 'the best class of rubble work in large flat bedded limestone, closely set and jointed in with mortar with at least one through bond stone to every ten square feet of walling; no excessive filling with spalls being allowed. All angles to be in extra large stones in and out bond.'

The stone used in this work was not up to the specification—in fact, it was of a very inferior quality and only fit for the most ordinary class of rubble walling. The backing was not laid with large flat bedded stone, nor with extra large stones in and out bond at the angles, as specified; nor was it laid with any regard to proper bonding either in itself or with the Nepean stone facing.

The portion of the wall which was taken down under our supervision was a very inferior class of work. The stone was not 'large flat bedded stones,' but stone of small size and irregular shapes. The walls were not properly bonded either in the use of large through bonding stones nor in the proper bedding of the stones to give good bonding as between stone and stone, and there was no attempt to build a homogeneous wall from face to back. The facing was built stone upon stone with no more bonding than was given by the irregular depth of the facing stone. The backing was built with an inside facing of rubble limestone, and the intermediate space between this filling and the Nepean facing was filled up with irregular stone without bond, too many spalls and an unnecessary amount of mortar.

In a building of this character and under the contract and specifications which required 'that the works are to be executed in a substantial and workmanlike manner and with the best materials of their respective kinds,' the walls should have been built with a thorough bonding of the different parts, one with the other. The fact that the face of the wall was of Nepean stone random courses did not prevent its being incorporated into and made part of the backing any more than if the facing had been of limestone. Many buildings in Ottawa are of random coursed limestone and the walls are homogeneous from the front to the back. If these random-coursed limestone walls are considered as homogeneous and built as such, then a wall faced with Nepean stone can likewise and should be built as a homogeneous wall.



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We find that there was no proper bonding of the Ohio cut sandstone to meet the requirements of the specification. This was particularly the case in the water table, where special care should have been exercised in placing through stones at such intervals apart as would have insured a thorough bonding of the cut stone to the masonry, and the water table at the angles should have been of large square stones.

We are of the opinion that there was not a single bond stone in the courses of the water table and that it consisted of stones without sufficient bed to meet the outward thrust of the Nepean facing above the tabling.

If three tons per square foot would be a safe load on walls as built in this tower, then from ten to fifteen would be an equally safe load on walls built according to the specifications. Kidder, an authority on building construction, allows three tons per square foot as a safe load on rubble walls of irregular stone, and for rubble walls with coursed hard stone, five to sixteen tons per foot, the same being built in lime mortar. The safe load upon a masonry wall is considered to be one-tenth of the load which would destroy or crush the wall.

We are of the opinion that the masonry used in the tower in question was of such a character that it would have been overloaded with even three tons per square foot, and that had it been of the quality required by the specifications it would safely have borne a load of at least ten tons per square foot.

While it is not possible to determine the loads concentrated at the ends of steel beams we are of the opinion that these loads would not exceed the safe load for masonry of the quality that should have been used.

With the inferior character of the walling up to the water table, and of the water table itself, the piercing of the walls below the water table at the quatrefoil openings, and the introduction of the steel beams to carry the overhang in the upper stage of the tower, produced a combination of circumstances that was bound to insure a collapse of the tower.

With the walls built as required by the specifications and the proper bonding of the water table into the backing, the use of extra large stone in and out bond at the angles, and block stone jambs at the quatrefoil openings properly bonded to the walls, the work would have stood, notwithstanding the defects in construction made by the piercing of the walls by the quatrefoil openings and the introduction of steel beams.

This contention is upheld by the fact that notwithstanding the collapse of the tower, the south jamb of the south quatrefoil opening in the east elevation remained in place although built of block stones 12 by 14 by 17, placed one upon the other without adequate or sufficient bond with the walling.

#### MORTAR.

The lime mortar used in this work was of fair quality; it had a fair quantity of lime, but was not in all cases equally or well mixed, and the sand was too fine for stone mortar.

#### FROSTY WEATHER.

We learn from the evidence that the upper stage of the tower was built during the months of November and December, during frosty weather. In our opinion, the upper portion of the tower should not have been built at this time, more particularly as the mortar used in the walls below the water table had not set, the weather not being favourable for setting of lime mortar.

In taking down a portion of the wall, we found that the mortar in the centre of the wall was still moist and could be easily crumbled in the hand, but on exposing the same to the air for a few days it set fairly hard.

The commissioners believe that the tower could and should have been built in a safe and satisfactory manner if reasonable intelligence and care had been exercised by the contractor, notwithstanding the defects in the constructional design before referred to and which we herebelow mention.



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We find that in the collapsed tower the quatrefoils were placed in the same position in relation to the water table and angle of the tower that they occupy in the old towers, but instead of being mere surface ornamental panels, as in the old towers, they are perforated so as to form windows, and on the inside of each there is an opening of four feet six inches wide by four feet high to springing of arch, these openings arched in brick. On the jambs forming the sides of these openings the outer ends of each of the twenty-one-foot steel beams were placed which supported the overhang of the north and south wall. The perforation of the walls at the quatrefoils in the collapsed tower weakened them at a point where their full strength should have been maintained and the placing of the steel beams almost immediately over the jambs of the openings at the back of the quatrefoils, caused a concentrated and eccentric load to be placed over the weakest point in the wall.

In the opinion of the commissioners, the perforations of the quatrefoil openings and the placing of the steel beams, as above described, was a serious error in design and construction, for which the Department of Public Works is responsible.

There was no good or reasonable cause why the quatrefoils should have been carried through the walls, as the necessity for lighting the interior of the tower at this point is not apparent.

The introduction of the twenty-four-inch beams to carry the eight-inch overhang was a mistake and unnecessary. It is not good construction to distribute a load upon two materials of entirely different qualities, such as rubble masonry and steel. The beams were unnecessarily deep and heavy, and their introduction into the work no doubt resulted in an injurious strain and concentration of loads impossible to estimate, more especially when the supporting walling was badly built.

If it was considered necessary to have windows at the quatre foils, several efficient methods of using steel without setting up unnecessary concentrated loads and strains could have been adopted.

Your commissioners believe that had this work received proper inspection and superintendence by a competent party during its progress, the error and faults in construction before mentioned would have been discovered and avoided.

#### SUPERVISION.

The supervision of the work by the department above the level of the first floor was of a most formal character. Practically there was no supervision of the work as it should have been supervised from the time the work reached the ground floor until the tower collapsed. Mr. L. F. Taylor was placed in charge of the work and was responsible to the chief architect, but he did not make any reasonable attempt to fulfil his duties. He admits that he paid no attention to the character of the masonry in the tower and that the upper portion of the tower was built without any supervision on his part whatever.

The character of the materials supplied and the work done showed clearly that for some reason or other he did not supervise the work, except in the most casual and indifferent manner, and we judge that while he may be a most useful and capable man in his own sphere he has little practical knowledge of construction or building, and is not competent to look after the erection of a building or deal with contractors.

In this case any architect reasonably competent would have detected the bad materials and workmanship by occasional visits to the work and would have also detected the defective arrangement by which the steel beams concentrated the load at four points and would have given instructions to the contractors as to the quality of the masonry to be used, at these points.

The defective constructive design does not appear to have come under the notice of the chief architect, as he states that he was not aware that any changes had been made from his instructions to make this tower the same as the two towers on the south elevation, and the fact that steel beams were introduced and quatrefoil openings made,



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appear only to have come to his notice after the collapse of the tower. The changes in construction such as we have mentioned above should have been referred to the chief architect before they were adopted and carried out.

Our findings as to the cause of the collapse of the tower are as follows:—

First. That the walls as built by the contractor were not according to the specification and that the bad quality of the work was sufficient cause for the collapse of the tower.

Second. That the plans and specifications prepared for this work were not as explicit and clear as they might have been; they were, however, reasonably and sufficiently clear to enable a contractor to determine the quality of the work required.

Third. Your commissioners consider that the constructional design of the tower at and above the quatrefoils and water tables and the introduction of steel beams in the manner shown on the drawings, were faulty and defective in that the quatrefoil openings weakened the wall at a point where the full strength should have been maintained, and the steel beams brought a concentrated and eccentric load upon the wall at its weakest point; the more serious defect of the two being, in our opinion, the introduction of the steel beams.

Fourth. That there was no proper and efficient supervision of the works by the department from the level of the ground floor upwards.

Fifth. That the main building, owing to the use of block stone in the backing, is safe, the work being of a substantial character. It may be that the facing is not properly bonded with the block stone backing. This we have no means of satisfactorily determining, as it would not be advisable to take down any of the Nepean stone facing.

Sixth. That it was inadvisable to proceed with the erection of the upper portions of the tower in the months of November and December, especially as the walling at and below the water table had been built late in the fall and the lime mortar had not had opportunity to set.

Seventh. That the contractor must be held responsible for the collapse of the tower in that he did not carry out his work in a good and substantial manner, in accordance with the plans and specifications, or take any precaution to see that the work was thoroughly well built at all points where it should be self-evident to any intelligent or practical builder that the construction shown required special care and attention.

Eighth. That the Department of Public Works is also responsible in that it did not properly supervise the work and detect and correct faults of construction as the work progressed.

S. G. CURRY,  
ALEX. C. HUTCHISON.